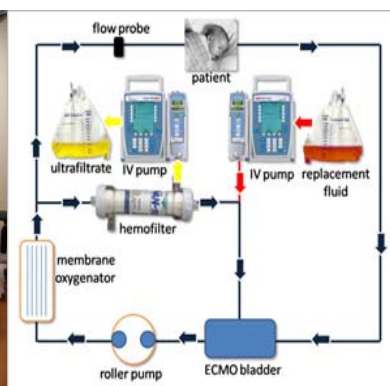
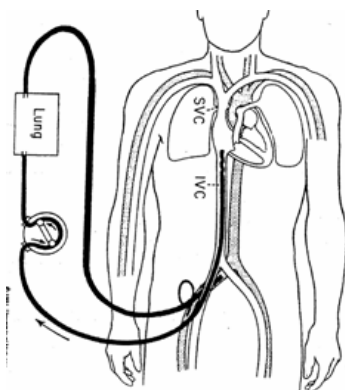


ECMO: Extra Corporeal Membrane Oxygenation,

ECMO SUPPORT FOR HEART AND/OR LUNG INSUFFICIENCY
AT THE DEPARTMENT OF CARDIOTHORACIC SURGERY
AT ULLEVAAL UNIVERSITY HOSPITAL
IN THE PERIOD 1998 TO 2008



STUD. MED. ZONIRA ABBAS

VED UNIVERSITETET I OSLO, DET MEDISINSKE FAKULTET

VEILEDER: KLIN. STIP. TORJUS WESTER

VED THORAX KIRURGISK AVDELING, ULLEVÅL
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Notat

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Søknad om å gjennomgå pasientmateriale ved UUS

Viser til søknad datert 15. okt 2008 om avdelingens støtte til å gjennomgå journalene til de pasientene som er behandlet med ECHLA ved Thoraxkirurgisk avdeling, UUS de siste 15 år. Avdelingen støtter dette arbeidet og ønsker dere lykke til. Denne pasientgruppen er svært heterogen, men jeg håper dere likevel kan samle kunnskap som kan støtte oss i videre bruk av denne behandlingsmetodikken.

Dersom journalgjennomgangen medfører at dere må lage et register som kan gjøre pasientene identifiserbare, må nødvendige formaliteter ivaretaes overfor personvernombudet ved UUS og Forskningsutvalget. (Se vedlagte brosjyre).

Med hilsen

Øystein A. Vengen
Avdelingsoverlege

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Abstract

Background: ECMO-treatment is a high-cost treatment with high mortality. Few good parameters to select patients to this treatment are described.

Aim of the study: To evaluate the results on ECMO treatment in our department, after 11 years of practice and to introduce a medical student to a clinical material.

Material and methods: The study was a retrospective one, where the material was all treated patients on ECMO between 1998 and 2008.

Results: 31 patients were treated, 10 women and 21 men. 25 patients had primarily a cardiac reason for ECMO-treatment, 6 had other causes (Lung embolism, drowning and intoxication). In the cardiac group there was a survival rate of 36%. Age gender, type of operation or comorbidity did not affect outcome. Limb complications were high in our material, but improved in the second period. The total prize of ECMO-treatment in our department was roughly 40 million NOK.

Conclusions: ECMO treatment is expensive and the patients have a high mortality rate. During the first 11 years of ECMO treatment in our department, our mortality rate and incidence of ECMO-treatment have been quite similar to other ECMO studies. Our limb complications have been high, but improving markedly in the second period, probably as a result of changed practice of cannulation in the femoral artery.

Introduction

Shock and cardiogenic shock

Shock is a condition with severe acute circulatory failure, where there is *a life-threatening inability of the cardiovascular system to maintain adequate tissue perfusion* (1).

During shock the state of homeostasis in the organism is disrupted, meaning that the cells are not receiving adequate delivery of fuels and oxygen. The patient's body fails to deliver sufficient oxygen to the mitochondria of cells, resulting in failure to sustain aerobic metabolism in the rate needed, with the consequence being irreversible cell damage. As cells die, the patient may acquire organ dysfunction or failure (2).

Based on etiology, shock can be divided into three main categories: cardiogenic, hypovolemic and distributive shock (caused by a peripheral vascular failure) (3;4).

Since this task is about a specific treatment of severe cardiogenic shock, we are not going to discuss the two other types of shock any further.

Cardiogenic shock (CS) is a result of myocardial pump failure. The causes for CS may be divided into either intrinsic or extrinsic. Myocardial damage, arrhythmias and myocarditis are examples of intrinsic, while heart tamponade (causing obstruction to outflow) or massive lung embolism (increased pulmonary pressure) are examples of extrinsic causes (5). Most commonly, CS arises from an acute myocardial infarction (AMI) or acute ventricular arrhythmias (6). An AMI can cause CS both by irreversible damage of at least 50 % of the left ventricular muscle mass or by causing free-wall rupture, acute ventricular septal defect or mitral regurgitation secondary to papillary muscle rupture (2;7). CS is a highly lethal condition, which results in death to 75% of patients unless immediate management is instituted (2).

Epidemiology: According to numbers from the United States, ischemic heart disease cause over 500 000 deaths annually, and is registered as the most common cause of death among adults. Coronary Artery Disease (CAD) forms the majority of patients with ischemic heart disease. Emergency departments in the U.S receive 5 million visitors each year with acute chest pain. In a typical emergency department population with acute chest pain, about 15 % of patients will have AMI and 25-30 % will have angina (7). This means approximately 7-800 000 cases of AMI annually, and a total of two million visits caused by ischemic heart disease. Cardiogenic shock is the most frequent cause of in-hospital-death from acute myocardial infarction (AMI), with an overall mortality of 50% and accounting for 50 000 to 70 000 deaths each year in the United States alone. The overall incidence of cardiogenic shock after AMI is about 6 to 8 % (7;8). CS occurs in 2-3 % of non-STEMI and 5-12 % of STEMI (ST-elevation myocardial infarction) (9).

Treatment of cardiogenic shock: In general, initial management of cardiogenic shock is focused on fluid resuscitation and supplemental oxygen. Preload reduction and diuretic agents should be avoided. Systolic blood pressure should be raised > 90 mm Hg with inotropic drugs, either beta agonists or phosphodiesterase inhibitor or combination therapy for synergistic effect. Use of inotropic drugs is considered palliative because there is no evidence that inotropic drugs improve survival and in fact will accelerate myocardial dysfunction by raising myocardial oxygen demand. Nonetheless, inotropic drugs do assist in stabilizing patients during assessment, transfer or before the definitive therapy is performed. Optimization of filling pressures and serial measurement of cardiac output allows for titration of the dosage of inotropic agents to the minimum dosage required to achieve the chosen therapeutic goals, which essentially minimizes the oxygen demand and arrhythmogenic potential. More specifically treatment of CS is to correct the cause. If possible, cardiac echocardiography or coronary artery angiography is performed to establish the anatomic cause for shock and the precise nature of cardiac pump dysfunction (10). In acute myocardial infarction, coronary reperfusion should be achieved promptly.

Mechanical assist devices:

In some cases, with CS refractory to all the above treatment possibilities, the patients can be treated with different mechanical assist devices for support of heart or lung function. There are several principles of assist devices but in our material we have used two, *Extracorporeal Membrane Oxygenation* (ECMO) and *Intra-Aortic Balloon Pump counterpulsation* (IABP). In our material these devices have often been used in combination.

ECMO is a mechanical assist device very similar to a heart-lung machine. It is used to support patients with severely reduced function of heart and/or lung. The ECMO circuit is a cardio-pulmonary bypass, with limitations. It does not have any reservoir, so it can not withdraw fluid from the circulation. The benefit compared to Cardio Pulmonary Bypass (CPB) is less complications during a long treatment period.

ECMO-treatment can be done either as Vein to Vein (VV)-ECMO or Vein to Artery (VA)-ECMO (11). VV-Ecmo is used when dealing with an isolated respiratory problem, but is insufficient to treat cardiac problems, a veno-arterial ECMO will provide both cardiac and pulmonary support. VV-ECMO is less traumatic to the patients, in some cases a VA-ECMO is converted to a VV-ECMO after recovery of heart function, before recovery of the lungs. The ECMO circuit consist of two cannulas, one draining venous blood from a central vein or right atrium, one delivering oxygenated blood back to an artery (VA-ECMO) or a vein (VV-ECMO). In addition to the tubing system, the ECMO circuit consists of an artificial lung called an oxygenator (where CO₂ is removed and O₂ is added), and a centrifugal pump that forces the oxygenated blood back to the circulatory system (11). In our department we use an ECMO system from Medtronic Incorporated.

The two cannulas (tubes) can be inserted in several ways. In some cases it is convenient to use the same tubes as used when the patient was on CPB during the open thoracic surgery, the tubes lying intra-thoracic. Most often the tubes are inserted via large veins, like the subclavian or femoral vein, while oxygenated blood most often is brought back via the femoral arteries. In some cases both tubes are placed on the same side, while others prefer one tube in each groin. To avoid limb complication in the same side as the arterial cannulation, the tube is often placed in a bypass graft.

ECMO-support can be used as a bridge to recovery, a bridge to transplant and in some cases bridge to a destination pump.

IABP (Intra Aortic Balloon Pump) is a mechanical assist device that is used as a temporary support in situations where the heart's cardiac output is insufficient to meet the oxygen demands of the body. Because IABP is easy to insert, it is the most widely used form of mechanical circulatory support (12).

The function of the IABP is to reduce the load on the heart in the systole and increase coronary perfusion in the diastole. This is done by a computer-controlled pump connected to a catheter inserted into the femoral artery and guided into the descending aorta. The catheter ends in a cylindrical polyethylene balloon placed approximately 2 cm from the left subclavian artery. The balloon is controlled by a computer regulating the flow of helium from a cylinder in to and out of the balloon, giving inflation and deflation of the balloon (counterpulsation). The balloon inflates at the start of diastole, increasing coronary perfusion, and deflates at the beginning of systole, increasing the cardiac output and decreasing the left ventricular stroke work and myocardial oxygen demand. In this way the balloon supports the heart indirectly. The inflation of the balloon can be triggered by the patient's electrocardiogram (ECG), blood pressure, a pacemaker, or by a pre-set internal rate (9;12;13).

Situations where there is indication of IABP may be: Failure to wean from cardiopulmonary bypass (CPB) after open heart surgery, cardiogenic shock, severe septic shock, post cardiac surgery or after large heart infarctions or severe heart failure (12;13).

IABP improves survival after thrombolytic therapy, but it may not improve survival after an acute mechanical catastrophe without successful revascularization or a surgical correction (7).

Economy/Ethics:

ECMO is a demanding therapy regarding both resources and expenses and the mortality rate in the adult patients with cardiac disease is high. In numbers from the U.S.A, the total hospital stay for each patient treated on ECMO is stipulated to cost between 20 000-90 000 dollars (14). We did not succeed in finding any concrete numbers in the literature for cost of ECMO treatment per day in Norway, but consulting staff at the department we learned that roughly estimated cost of ICU treatment per patient per day is 100 000 NOK. ECMO treatment is probably at least as expensive.. This is equal to about 13 000 USD/day. Since less than a third of the patients treated on ECMO for cardiac reasons survive, the prize per saved life is high. Is it worth spending so much money on this group of patients, or could the money have been used more effectively on other patient groups?

Selecting patients for ECMO treatment:

Since the costs and mortality in treatment of patients on ECMO is so high, criteria for selecting patients with a fair chance of recovery from those who have not, has been the main aim in several studies. A high pre-ECMO CvO_2 is associated with improved outcome (15). Also a low lactate level indicates a better prognosis (16).

Aim of the study:

The main aim of this study was to introduce a medical student to the planning of a retrospective quality-control study. This involved studying the literature on different topics relevant for the study, including cardiology, cardiothoracic surgery and different assist devices, intensive care medicine as well as economy and ethics in high cost medicine. The second aim was to evaluate the department's experience with ECMO treatment the past 11 years.

Material and methods

Material

Our material includes all patients treated with Extracorporeal Membrane Oxygenation (ECMO) for heart or/and lung insufficiency in our department since the first patients were treated with ECMO in 1998. As in most other materials regarding treatment on ECMO, the material is quite heterogeneous in all aspects. Since this was a quality control study, we did not know the patient's age, gender, co-morbidity, operations, further treatment and outcome ahead of the study, and these parameters will be presented as results.

Methods

The study is a retrospective one, where all information was taken from the patient's medical records. This was done with kindly permission by the head of department of cardiothoracic surgery. The patients were coded with a study number, and data was collected in a non-identifiable way. Previous studies on the same group of patients were used for deciding which parameters to look for.

We came up with following variables: Age, gender, BMI, co morbidity, previous operations, acute vs. planned surgery and surgical procedure. Operation time and indications of ECMO were also noted. We were particularly interested in the patient's clinical status at the time they were weaned on ECMO. These observations included central hemodynamic parameters (mean arterial pressure (MAP), central venous pressure (CVP), mean pulmonary artery pressure (MPAP), blood sample values like hemoglobin, oxygen saturation, CO₂, central venous oxygen saturation, lactate, and base excess and pH).

While on ECMO, these parameters, as well as clinical data (Body temperature, clinical evaluation of peripheral circulation, heart rate, urinary output and overall fluid balance), ECCO-cor, blood samples indicating infection (CRP, leucocytes), organ failure (Bilirubin, creatinin, urea) were noted each day on ECMO and also two days after successfully weaning off ECMO.

To decide the presence of organ failure (lung, kidney and liver), the definitions in *SOFA score*

(Sequential Organ Failure Assessment score) were used. This is a scoring system used to track patient status during stay in an intensive care unit, and is used to determine the extent of organ dysfunction/failure (17-19). In all cases, we found that the patients had the most severe category of cardiac failure.

Amount of bleeding (measured as number of units with erythrocytes needed), presence of infection or organ failure, number of reoperations were noted. Limb complications, either as compartment syndrome, ischemic leg or need of amputation was noted.

The final outcome: 1) Death on ECHLA, 2) successfully weaned off ECHLA, but death from complications during hospital stay and 3) survivors. There have been used various definitions of survival in different materials. Some materials define survival as 30 day survival and some use discharge from hospital alive. In our material, what definition we use, does not affect the results.

Results

At our department, 31 patients were managed with ECMO between January 1th 1998 and December 31th 2008. With a total of approximately 5000 open heart operations in our department during these past 11 years, this gives an incidence of 0,6 % of cardiac surgery patients treated with ECMO. Mean age in the patient population was 51,3 years (median 57, range from 9 to 77 yrs). The material included 10 females and 21 males.

The patient material was quite heterogeneous and we found it convenient to divide the material into four main groups based on diagnosis/clinical condition immediately before initiation of ECMO treatment:

- Group 1)** Patients admitted to hospital for *planned heart surgery*.
- Group 2)** Patients admitted to hospital for an *acute heart condition* requiring surgery, *without preoperative cardiogenic shock*.
- Group 3)** Patients admitted to hospital for an *acute heart condition* requiring surgery, *with preoperative cardiogenic shock*.
- Group 4)** *Other causes* (massive pulmonary embolus, drowning, intoxication).

Number of patients, age, gender and survival in the different groups are presented in table 1.

Group	Number of patients (%)	Age (mean/ median/ range)	Gender (female/male)	Survival (discharged from hospital alive)
Group 1	11 (35 %)	53,7/ 59/ (33-77)	3/8	36%
Group 2	5 (16 %)	55,4/ 57/ (37-68)	2/3	40%

Group 3	9 (29 %)	58,2/ 60/ (38-75)	2/7	33%
Group 4	6 (19 %)	32,8/ 27/ (9-64)	3/3	0

Table 1: Diagnosis groups related to number, age, gender and survival

The mean age in the first three groups forming the cardiac population, was very similar, around 55 yrs (median age 59, range 33 to 77). The non-cardiac group stood out with a much lower mean age of 32,8 yrs, with median age 27 (range from 9 to 64).

We chose to take a closer look at the planned surgery group (group 1) assuming that this group was less heterogenic regarding pre-operative status, compared to the other three groups.

Gen der/ Age	Preoperative Ejection Fraction	Reoperation	Comorbidity	BMI
M 61	Slightly reduced	Yes	Previous cerebral stroke,	24,5
M 77	47	Yes	Diabetes type II. Atrial fibrillation. Cerebral stroke. Pulmonary hypertension.	23,2
M 45	40	Yes	Previous AMI.	23,4
M 61	30-35	No	COPD, previous AMI, Cardiac failure. Diabetes type II.	28
M 61	"Good"	Yes	Previous AMI. Previous lung embolism.	26,5
M 41	60	No	SLE , chronic renal failure. (TX)	-
F 57	45	No	COPD, Diabetes type II Insulin. Atrial fibrillation.	29,7
F 63	68	Yes	None.	28,3
F 75	75	Yes	COPD, cardiac failure.	35,9

M 59	47	No	Previous AMI.	26,5
F 33	-	Yes	None.	29,6
	6 patients slightly reduced	7/11 (63%)		28

Table 2: Group 1. Possible risk-factors for need of ECMO-treatment: Age, gender, ejection fraction, reoperation, comorbidity and BMI. (Survivors marked in green).

We wanted to see if we could find any predisposing factors associated with increased risk of needing ECMO after planned cardiac surgery. An overview of possible predisposing factors for ECMO in the group admitted for planned cardiac surgery is displayed in table 2.

As this table shows, seven of the eleven patients in the planned surgery group were having a reoperation.

None of the four survivors in this group had COPD or previously known heart failure, only one had had an AMI. However six patients had a reduced ejection fraction ahead of surgery. Mean BMI among the survivors in this group was lower (26,0) than among the non-survivors in this group (28,6).

We found that mean duration of surgery in group 1 was 6,7 hours, range 2,1 to 11 (calculated from the eight patients with known surgery duration, three patients with surgery time unknown).

Survival/ causes of death

The overall survival-rate in our material (including all four groups) was 29% (nine patients). The causes of death according to their medical records were as shown in table 3.

Causes of death	Number of patients
Cardiac cause	5 (22 %)
Brain death	10 (45%)
Bleeding	1 (5 %)
Sepsis/multiorgan failure	5 (27 %)
Total	22

Table 3: Causes of death

In our study, 45 % of deaths were caused by cerebral causes. In most cases the diagnosis brain

death was based on a cerebral angiography. In two cases it was due to patients not waking up and showing no clinical signs of brain activity. Sepsis/multi-organ failure was the second most common cause of death (27%).

In published articles on ECMO treatment, the material is often divided in cardiac reasons and pulmonary reasons for ECMO. For further evaluation of survival, we therefore divided the material in two: patients suffering primarily from cardiac cause (Sum of group 1, 2 and 3 = 25 patients), and patients developing cardiogenic shock as a result of extra-cardiac conditions (group 4 = 6 patients).

The cardiac group:

The survival rate among patients suffering primarily from cardiac cause (excluding group 4), was 36% (9/25). Of these nine patients, all but one had a recovery of heart function, while one patient was heart transplanted. Six of the discharged patients are still alive today (24%) (Range one to 11 years follow up time). Three patients died after discharge, about two months after ECMO treatment.

Of the 16 patients in the cardiac material that did not survive, 13 died on ECMO. Three patients were recovering heart function and were weaned successfully from ECMO, but died later before discharge of non-cardiac reason (Un-controllable bleeding in one patient and irreversible brain damage in two).

	Total	Survivors	Non-survivors in cardiac group
Number of patients	25	9	16
Age		Mean 55 Median 59 (33-77)	Mean 56 Median 59,5 (33-75)
Females	7	29% (2/7)	71% (5/7)
Males	18	39% (7/18)	61% (11/18)
Diabetes	4	11% (1/9)	19% (3/16)
COPD	4	0	25% (4/16)
When on ECMO*	25	6 directly from CPB. 1 after HLR and defibrillation 1 after 5 hours, 1 after 13 hours	7 directly on ECMO 7 after attempts for 15 minutes to 20 hours with pressors and IABP 2 directly after HLR in the operating theatre.

Pre-ECMO pH		Median 7,16 (range 7,10-7,35)	Median 7,08 (range 6,90-7,28)
Reoperation	9	56% (5/9)	25% (4/16)
Acute surgeries	14	36% (5/14)	64 % (9/14)
Planned surgeries	11	36% (4/11)	64% (7/11)
Initial MAP		Median 55 (range 35-60)	Median 55 (range 35-70)

Table 4: Comparison of predisposal factors between the 9 survivors and the 16 non-survivors in the cardiac group.

In table 4, we have compared the survivors and non-survivors in the cardiac patient-group (group 1-3), to see if there may be any predisposing factors for mortality among our cardiac ECMO patients.

Among the survivors 5 of 9 (56%) of the patients were having a reoperation, while among the non-survivors 4 of 16 (25 %) patients were having a reoperation.

There was a small difference between the survivor and non-survivor group according to when they were weaned on ECMO. Six of nine patients in the survivor-group went directly from CPB while only seven of 16 in the other group went directly on ECMO from CPB. The groups were different in pre-ECMO pH levels as well (See table 4). Pre ECMO mean arterial pressure in the two groups showed no difference.

Four patients in the cardiac group had chronic obstructive pulmonary disease, COPD. None of the 9 survivors had COPD, while 25% of the non-survivors did.

Among the nine survivors, five patients had pneumonia, four patients had kidney failure of whom three patients required dialysis. Four patients had had a liver failure, one severe, and three moderate, according to SOFA score.

Group 4:

All six patients in group 4 died. The reasons of death were in all cases brain death. This group consisted of four pulmonary embolisms, one drowning and one patient with intoxication. In two cases of pulmonary embolism, embolectomia was performed. In either cases, the patient could not be weaned off CPB and was placed directly on ECMO. In the other four cases the patient was treated with ECMO alone. In five of the cases the patient was severely acidic ahead of treatment with pH values from 6,73 or lower. Both median and mean pH values for the group was 6,70 (Range 6,48-7,28).

Economics

The total number of ICU days for all 31 patients was 400. 150 days were used on two patients alone, both survivors, but one of them died two months after ECMO treatment. Usually we calculate a cost of 100 000 NOK per day at the ICU. This gives a total prize of roughly 40 million NOK on 31 patients during 11 years. At least 990 units of erythrocytes were used. The number of surgical procedures for bleeding and suspected heart tamponade were at least 50, mean 1,6 (Range 0-7). Details on duration of ECMO, ICU-days, numbers of SAGs needed and limb complications among the 31 patients are presented in table 5, comparing the survivors and non-survivors. As we see in table 5, the non-survivors were shorter time on ECMO than the survivors. As most of them died on ECMO, the total number of extra ICU days in this group was not more than 30.

	Days on ECMO Median, (mean, range)	Extra ICU-days (Median, mean range)	Number of SAGs (Median, mean range)	Limb complications
Survivors	5,7 (5, 2-10,5)	31 (20, 10-80)	39,8 (36, 16-66) Total 320	4 fasciotomies
Non-survivors	2,9 (2,7, 0,7-7,5)	10 (10, 5-15) (3 patients)	28,9 (18,5, 5-81) Total. 670	5 necrotic legs 6 Fasciotomies

Table 5: Duration of ECMO-treatment, extra ICU days, need of transfusion and limb complications.

ECMO-treatment (First compared to second half of patient material)

Dividing our material in two (at patient 16) we get P1 (patients 1-16), and group P2 (patients 17-31). The first group is from the first seven and a half years after this treatment was started in our department while the rest was treated during the next three years. Survivors in the first group were 4 patients, five survivors in the second.

Limb complications were reduced in the second period. In the first period, four legs became ischemic in addition to six fasciotomies, while only one leg became ischemic and three fasciotomies were performed in the second period.

Discussion

There are clearly limitations in a retrospective study, and with such a heterogeneous patient group as we have in our study. Data of interest is not registered in all patients. Also, the medical records that the diagnosis and other information in the study are based upon often leave out specifying grounds for the facts they give. The medical records consist of information from different medical doctors with each their way of defining the various conditions that are reported. The patients in our study are a very heterogeneous group with many variables affecting our data of interest. When considering the limitations in the study, it seems to be little point in calculating statistical values/performing statistical analysis. Still, it may give some indication.

An incidence of 0,6 % treated with ECMO among all patients treated with cardiac surgery in our department corresponds with numbers from other published articles (16;20).

The mean age in our cardiac group also corresponded well to other materials (16).

We had twice as many men in our material than women, this probably represents the prevalence of cardiac diseases in men and women in general in our society.

The Extracorporeal Life Support Organization (ELSO) reports a survival rate in cardiac ECMO-causes of 33% (21). Recent articles report the same numbers from the most recent ELSO registry report (22). Our survival-rate in patients with (primary) cardiogenic cause for ECMO treatment (36%) corresponds well with the ELSO reports. We chose to include the patient who was heart transplanted in the survivor group. Since the only other information we have about his condition is that he died two months later, this can clearly be discussed.

Long-time survival in our material was 24%, also this corresponds with ELSO.

In the group with non-cardiac conditions as cause of cardiogenic shock (group 4 in table 1), the mortality rate was 100%. In other papers, the patients suffering from respiratory failure has a better chance of surviving ECMO treatment than the cardiac patients. In our study this groups' bad outcome were probably due to the severe prehospital condition of these patients. One patient with drowning, one patient with intoxication and three pulmonary embolisms were all extremely acidic at the time they were put on ECMO (pH 6,48-6,73), and also showed clinical signs on irreversible brain damage.

Quite surprisingly, age and preoperative condition, (planned surgery, acute without cardiogenic shock or acute with preoperative cardiogenic shock) did not seem to affect outcome. In the cardiac group mean median and range for age was almost exactly the same in the survivor and non-survivor group.

Being reoperated seems to be a risk for needing ECMO, however it also may seem as patients having done a planned reoperation may have a better prognosis than the other patients when on ECMO (Table 4).

In our study we found that cerebral cause was the most common cause of death among our

patients, while sepsis/multi-organ failure was the second most common. A larger study in Ann Thorac surgery 2006 (23) reported 131 patients supported with ECMO, and multi-organ failure being the most common cause of death among these.

One reason for this difference may be that ECMO-support was discontinued due to clinical brain death in several patients in the non-survivor group. As shown in table 5, time on ECMO were shorter in the non-survivor-group than in the survivor group, and treatment have in some cases been terminated early, based on cerebral angiography before recovery of heart function and development of multi organ failure or sepsis. This may also partly explain why we have fewer patients successfully weaned off ECMO than other studies (16), without impaired survival.

A cerebral angiography early in the ECMO treatment might help with identification and evaluation of these patients at an earlier point and thus help optimize ECMO-treatment and improve resource utilization in the future.

One could ask if pre-ECMO pH could also be a predictor of recovery, as shown with CVO₂ (15). In the cardiac group median pH only showed minor differences between the survivor and the non-survivor groups. However, seven patients in the non-survivor group had lower pH than the lowest pH measured in the survivor group.

We could not find pre-ECMO CvO₂ in all our patients. We can therefore not say anything about CVO₂ as predictor of outcome in on our study

Pre ECMO mean arterial pressure (MAP) showed no difference between the survivors and non-survivors. It is remarkable that two patients in the survivor-group had a MAP for several hours at 35-40 without any neurological sequelae.

With a total prize of 40 million NOK one can certainly ask whether it is a correct use of money. Only six patients lived more than two months after ECMO-treatment. This gives a total prize per saved life of 6,7 million NOK. This may seem as a high prize, but in our material three survivors were 40 years and younger. Two other survivors were in their late fifties while one patient was 77 years old. A modest guess will be that this treatment can save at least hundred years of life. The prize per saved year of life will then be 400 000 NOK, a prize that probably is not higher than for some other patient groups, for instance advanced cancer therapy.

During the last one-two years, we have been given an impression that follow-up of patients on ECMO has improved. There are mainly three factors we have seen: Antibiotic treatment for a suspected infection has been started earlier, almost daily bronchoscopies have been done to improve lung-function, in addition better control of bleeding and fluid-loss. The latest patients have had no episodes with low Hb concentration or episodes of hypovolemia, which was quite frequent some years ago. Whether this possibly improved follow up may have improved

survival is not sure, but four of the last six treated patients have survived.

During the second period of treatment in our department, there have been fewer limb complications. This is probably because most artery cannulas now are inserted in a bypass graft, not directly in the artery, as they used to be earlier.

Conclusions

Selecting patients likely to profit from ECMO treatment is hard, as age or pre- ECMO condition does not affect outcome. During the first 11 years of ECMO treatment in our department, our mortality rate and incidence of ECMO-treatment have been quite similar to other ECMO studies for patients suffering from primarily cardiac causes, but patients suffering from other causes have a 100 percent mortality in our material. This may be due to an irreversible circulatory condition prior to ECMO treatment. Our results in the cardiac group may have been improved during the last 3 years. In our material a low pre-ECMO pH seems to be associated with a poor prognosis.

Our limb complications have been high, but improving markedly in the second period, probably as a result of changed practice of cannulation in the femoral artery.

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